

COMPACTION OF CONCRETE BY INTERNAL VIBRATION

The purpose of this bulletin is to explain briefly why and how concrete vibrators are used; and to bring to light some new information on the performance of concrete vibrators under different conditions.

WHY VIBRATE?

The action of vibration is to set the particles in the fresh concrete in motion; thereby reducing the friction between the particles and giving the mixture the mobile quality of a thick fluid so that gravity and the displacement of entrapped air will cause it to settle easily into place. By thus consolidating the concrete quickly, "stiffer" or "drier" mixes can be poured than would otherwise be possible. It has been proven that (up to a point) the drier the concrete, (that is, the less water in it), the better the quality throughout and the greater the strength. Drier mixes also make the concrete more water tight, increase resistance to weathering, and create a better bond between concrete and reinforcement. Because vibration causes much of the entrapped air in the concrete to rise to the surface, honeycombing is prevented. Also, vibration eliminates most of the air pockets between the concrete and the vertical forms.

For these reasons, most job specifications require vibration. For example—(here is a typical excerpt from a specification): "vibrators shall be of a sturdy construction, adequately powered, and capable of transmitting to concrete no less than 9,000 impulses per minute. The vibrations shall be sufficiently intense to cause the concrete to flow or settle readily into place and to visibly effect the concrete over a radius of at least 18 inches when used in concrete having 1" slump. A sufficient number of vibrators should be employed so that the required rate of placement vibration is maintained throughout the entire volume of each layer of concrete and complete compaction is secured. At least one extra vibrator should be on hand for emergency use."

DIFFERENT TYPES OF CONCRETE VIBRATORS

Essentially all internal concrete vibrators have a "head" which must be immersed in the concrete. The head is tubular, and contains a bearing-mounted eccentric on the inside, which rotates at high speed. When this eccentric (which is merely a weight whose center is offset from its axis) rotates, it has the effect of a whirling weight on the end of a string. The centrifugal force which is generated creates the vibration; each revolution is considered one cycle of vibration.

MOTOR-IN-HEAD TYPE

The Stow YUB 60 Cycle motor-in-head vibrator can be plugged into regular 115V house current. As the name implies, the motor is built into the head itself, along with the eccentric. This unit lends itself easily to "one-man" operation. However, the YUB does have limitations since the head size cannot be less than 2¾" in diameter, due to the extreme difficulty of building a smaller motor which will hold up under the constant vibration.

If the unit is run free of the concrete for any length of time or is operated on low voltage, "burn-outs" can occur.

The "hy-cycle" type is similar to the 60 cycle motor-in-head vibrator except that it operates off a 180 cycle generator, which means the contractor must have a special generator.



Stow 400G Gas Vibrator on floor slab.

The head size on Stow hy-cycle vibrators is 1¾" or 2½". Since these units do not have brushes in them (they are 3-phase motors), the maintenance cost is generally lower than the 60 cycle motor-in-head vibrator. Hy-cycle vibrators are available for use with either 110 volt or 220 volt hy-cycle generators. This type vibrator is most popular for use on highway bridges, because one man can operate the unit even though there is no source of electricity on the job other than the generator, and because the hy-cycle vibrator delivers greater amplitude of vibration than the 60 cycle motor-in-head type.

FLEXIBLE SHAFT TYPE

The most popular type of vibrator for general use is the "flexible shaft" type. It is driven either by a gasoline engine or a universal motor. It has a flexible shaft (similar to the speedometer drive on a car, only heavier), which drives the eccentric inside the vibrating head. Flexible shaft type vibrators are the most popular because:

1. Less maintenance is generally required than with other types.
2. These units are more versatile. There is a greater variety of head sizes available (1¾", 1¼", 1⅝", 2", 2½"), and flexible shafts are available in different lengths; by coupling flexible shafts together, lengths up to 35 ft. are possible. Of course the size of the motor has a bearing on the maximum length which can be used.
3. In recent years, universal electric motors have been made lighter in weight, yet they deliver either the same or greater horsepower. Thus, with the ¾ H.P. (71E) or 1⅓ H.P. (130E) sizes, one man can carry and operate the vibrator at the same time. With a gas-powered unit or a larger motor, it would be necessary to set the power plant down at one point while the operator manipulates the flexible shaft in the concrete. Often a second man is required to move the power source around.
4. Normally, these units maintain speeds in ranges from 9,000 to 13,000 vibrations per minute and with relatively high amplitude.

EFFICIENCY OF CONCRETE VIBRATION

Because time is important on any job, it is imperative to select the vibrator that will consolidate the concrete in the shortest possible time. Actual tests have shown that vibrating efficiency increases as the centrifugal force transmitted to the concrete increases. This holds true up to a speed of about 10,000 vibrations per minute, after which efficiency increases only slightly with the increased centrifugal force caused by higher speed. The centrifugal force generated is affected by 3 factors. Speed is the most important factor since the centrifugal force varies directly as the square of the speed. This is why it is important to run the electric vibrators at full voltage. Low voltage reduces speed which in turn reduces the centrifugal force even more. For example, using the curves on page four, note in Fig. 3 that if a 130E vibrator with the 2" #2038 head were to be used at 90 volts instead of 115 volts, the speed of the motor would drop from 10,300 vibrations per minute to 8,000 vibrations per minute. Fig. 6 shows that the centrifugal force would drop to 500 lbs. or a reduction of 37½%. Therefore, always follow the recommendations for wire size for extensions.

Also, the amplitude of vibration (which is the actual distance that the head moves as it vibrates) is important, for the centrifugal force increases directly with this amplitude.

The third factor affecting the centrifugal force is the weight of the head. Therefore, the largest possible head should be used. Of course, the amount of power put into the vibrator is important, too, because with low power, particularly in a stiff mix, the concrete can dampen the vibration down to the point where it has little actual effect. Therefore, it is important to have power enough to run the vibrator at a sufficient amplitude and speed when immersed in the concrete.

EXTENSION WIRE SIZES

Motor Model No.	Max. Length	Wire Sizes
200E	50 ft.	No. 12
200E	100 ft.	No. 10
200E	Over 100 ft.	No. 8
130E	150 ft.	No. 12
70E	150 ft.	No. 14

SELECTING THE VIBRATOR

Selection of the correct flexible shaft vibrator for the job is actually simple. For most general construction jobs, 2 inch or 2½ inch diameter vibrator heads work best. However, if thin wall sections are to be poured or the placement of reinforcing will not permit the use of the larger size, the smaller diameter vibrator heads—1½", 1¼" or 1⅜"—are recommended. The Stow catalog gives complete information as to which power units are used with the different size heads and the lengths of the available flexible shafts. Stow gasoline-powered vibrators have adequate power to maintain a top vibrator head frequency of 10,200 vibrations per minute (at 3400 R.P.M. engine speed) for all recommended flexible shaft and head combinations.

Because electric flexible shaft vibrators are the most popular, the remainder of this bulletin covers electrics only. To

select the size motor and head from among Stow's 3 different size motors, use Table 1. It contains information compiled through tests on these vibrators. When vibrating, use a pattern of immersion as shown in Fig. 1 (a 50% radial overlap) to insure complete coverage.

The Data Compiled Includes:

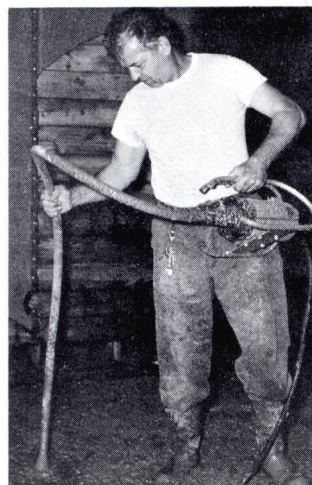
- (A) The compaction capacity in cubic yards per hour (which varies some with stiffness and the particular components of the mix).
- (B) The distance between head immersions "P" used in compiling this data.
- (C) The approximate head speed in vibrations per minute when used in 1" slump concrete. (Without going into detail, slump is a measure of the consistency of wet concrete from 0" to approximately 6", with 0" being the stiffest possible.)
- (D) The peak-to-peak measurement of the amplitude of vibration measured in air.

PUTTING THE VIBRATOR TO WORK

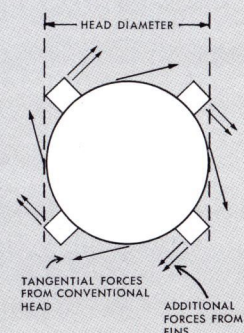
Before using the vibrator, please check the maintenance instructions in the parts book. Also, be sure that the flexible shaft is attached properly to the motor and the head to the flexible shaft. Use the flexible shaft in as straight a position as possible and *do not bend the flexible shaft sharply at any point*. Sharp bends may cause a permanent kink, requiring early replacement of the flexible shaft.

If the vibrator is not brand new or there is any question about the line voltage, frequency of vibration can be checked by placing a simple low-cost test instrument against the vibrator head. The amplitude can also be checked by applying a special Stow gummed label which serves as an "Amplitude Measuring Device."

The concrete is normally placed in the forms in layers about 12 to 18 inches thick in a manner which forms a fairly level surface. The vibrator head is inserted vertically into the top of the pile. Inserting the head into the side of the pile to make the concrete flow is bad practice, actually causing segregation of the aggregate from the mortar. When the surface has become fairly level, then the head should be immersed and generally moved in the pattern shown in Fig. 1 (check Table 1 for "P"). Immerse it for 5 to 10 seconds (until air stops rising) and then withdraw it slowly to let the concrete fill the void left by the head. The head should be completely below the surface when vibrating, to keep the head cool. When vibrating a thin horizontal slab, the head can be used in a horizontal position.



STOW FIN-HEAD



MAINTENANCE TIPS

Periodically check the motor for brush wear and replace brushes when they wear down. Also, check to see that concrete and/or foreign material do not get into the motor.

Check the head carefully for wear. If the head is permitted to wear through, the inside of the head would be damaged,

TABLE 1

HEAD MODEL NO. & NOMINAL DIA.	MOTOR MODEL NO.	2 COMPACTION CAPACITY CUBIC YARDS PER HOUR	3 DISTANCE BETWEEN HEAD IMMERSION—P	4 APPROXIMATE HEAD FREQ'Y 115V—1" SLUMP	5 PEAK TO PEAK AMPLITUDE IN AIR
9031— $\frac{1}{8}$ "	71E	1½—2½	4"	12,900	.072
12031 1238— $\frac{1}{4}$ "	71E 130E	3—5	7"	11,400 12,700	.072
1638— $\frac{3}{8}$ "	130E 200E	6—11	11"	10,800 12,000	.092
2038—2"	130E (1) 200E	12—20	15"	10,200 11,200	.119
2538—2½"	200E	20—30	20"	10,000	.123

- TABLE 1**
- 1 This combination is not recommended for shaft lengths over 7 ft.
 - 2 Compaction Capacity is based on 50% radial overlap (see Fig. 1).
 - 3 To insure complete coverage follow head placement pattern shown in Fig. 1.
 - 4 These head frequencies are approximate and will vary some with slump and length of shafting. For frequencies at reduced line voltage see motor performance curves.
 - 5 These values are representative of actual instrumentation readings at the tip.

thereby overloading the motor. The overload would cause over-heating and possible burn-out or breakage of the flexible shaft. To prevent this, replace the head when it has worn down to the minimum diameter specified in the head parts book. Also, it is important to watch for any slowing down or heating up of the motor. Both of these conditions indicate that the motor is being overloaded. Should this happen, replace the vibrator head immediately. Actually, promptness in correcting this situation results in lower costs, since at this point it may be necessary to replace only the shell of the vibrator head. Delay may require replacement of bearings and an eccentric. The flexible shaft should be lubricated in accordance with instructions in the parts book.

FIN-HEADS

Stow has available $\frac{1}{8}$ ", $\frac{1}{4}$ " and $\frac{3}{8}$ " "Fin" heads which are similar to round heads except that they have four fins spaced around the diameter of the head. Note from the diagram of this head that it will fit down between reinforcements in narrow forms just as easily as a round head. The fins do not protrude any further on the sides than the diameter of the head. However, since the forces generated by the centrifugal force are tangential to the head, the fins, through the greater surface area they provide, move a greater volume of the concrete with each "punch" of the vibrator head. The fin head also considerably increases the life of the shell of the head including square heads. However, where plywood forms are used, the fins are apt to mar the forms.

CONCLUSION

While there is still much to be learned about concrete and vibrating concrete, a competent operator can do a superior job of compacting concrete with Stow vibrators.

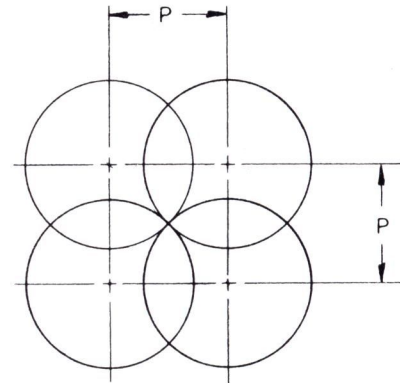


Fig. 1

Compaction Coverage with 50% Radial Overlap

Vibrator heads should be immersed in a vertical position for about 5 to 10 seconds, then withdrawn slowly to let the concrete fill the void left by the head.

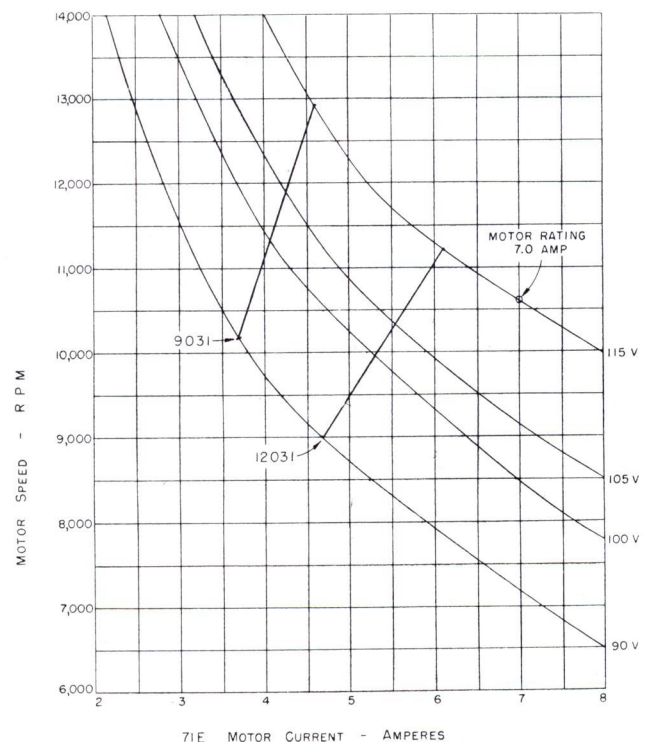


Fig. 2 Motor Performance Curves
(For 71E Vibrator)

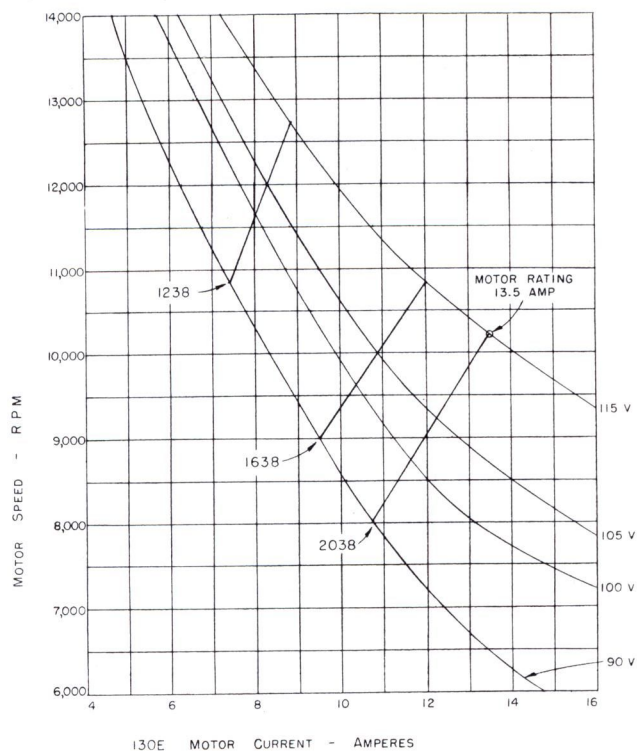


Fig. 3 Motor Performance Curves
(For 130E Vibrator)

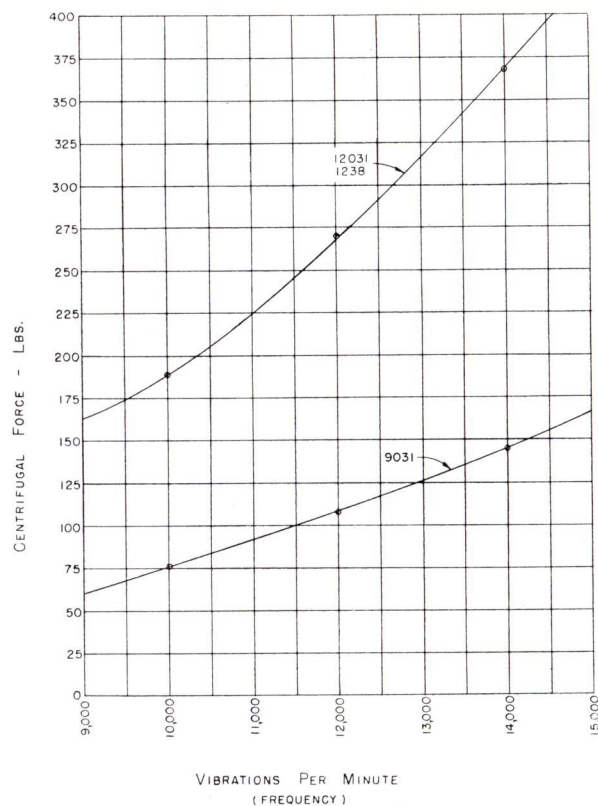


Fig. 5 Centrifugal Force Curves

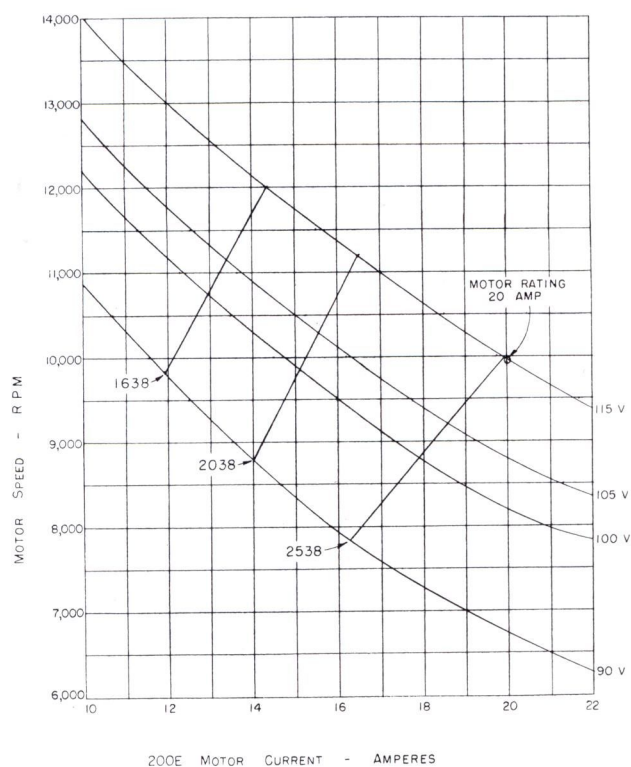


Fig. 4 Motor Performance Curves
(For 200E Vibrator)

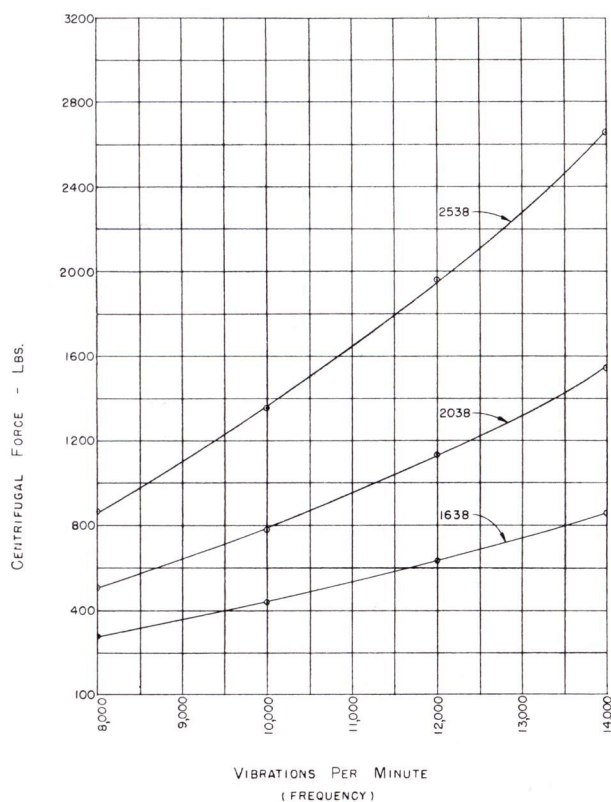


Fig. 6 Centrifugal Force Curves